A win-win for everyone? Demand-side flexibility and people's activities.

Oxford Energy Colloquia: Jacopo Torriti, Professor of Energy Economics and Policy, University of Reading

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The pressing need to accommodate increasingly large shares of intermittent renewables into our energy systems has sparked the interest in making the demand-side play a more active and dynamic role when it comes to balancing the systems. But what are the best ways to turn the demand-side into a flexible component that assists in system balancing?

Up until relatively recently, the demand side had been consistently seen as a passive component of the systems, and the balancing responsibilities fell almost entirely on the supply side. However, it has become quite clear that as the transition towards low-carbon systems progresses, this 'load following' approach will not provide the necessary means to ensure a constant demand-supply balance.

In recent years, demand-side flexibility has been hailed by many as a win-win situation. But is that really the case?

In this talk, Professor Jacopo Torriti explored with us the meaning of demand-side flexibility, as well as the implications of the deployment of certain demand-side flexibility programmes and potential opportunities to improve the effectiveness of measures seeking to make the demand-side more flexible.

Timing of residential electricity demand

Demand for energy – and for electricity in particular – is not constant throughout the day. There are points in time where demand rises to levels substantially higher than those normally observed, and this is what we call peak demand.

But what is peak demand about? Peak demand is about the capacity of the infrastructure that we build. But it's also about the society we live in, the synchronisation of the things people do while they go about their daily lives, and the challenges faced by our infrastructure when we're all doing things at the same time.

Peaks occur every day, but their intensity varies depending on the type of day, the season, the year and so on; at the moment, this peak ranges between some 50 - 55 GW.
Studying these peaks is important because they have some very clear and tangible impacts on the price and the carbon intensity of the energy we use. But characterising these peaks is not an easy task.

Under normal circumstances, a given family lives in the same house and makes use of roughly the same energy-consuming devices every day. However, even if we focused on this same family, living in the same house and using the same appliances during the same season of the year, huge differences may be observed in their energy consumption patterns.

Perhaps the simplest example of this variability is the difference in energy consumption during weekdays and weekends. There is a rather simple explanation for this variability: people just do different things – or the same things but differently – during weekdays and weekends. But what are those differences? Can they be measured in any meaningful way?
These are but a couple questions that with a closer look at different times – and different timescales – might help address.

Perhaps not surprisingly, some of the clearer differences that distinguish energy consumption patterns among different types of households are associated with the presence of dependent children. For instance, the consumption patterns of households with dependent children show a clear tendency to start engaging in energy-intensive activities earlier in the evening compared to households without dependent children. Some cultural differences are also clearly reflected in the daily energy consumption patterns of households. For instance, a comparison between energy consumption patterns of German and UK households reveals that while Germans tend to prefer having hot meals at lunch time rather than at dinner time, the opposite is true for Britons. Insights such as this can be provided by the analysis of the variations of the energy demand associated with the activities, food preparation in this case, households engage in throughout the day.

Demand-Side Flexibility

The deployment of demand-side flexibility programmes has been hailed as a win-win situation, more and more often in recent years. But is that really the case? The truth is that this conclusion might just have been drawn based on incomplete results and limited evidence, and that there is still much to be learned about the implications of the implementation of these kind of measures.

Additional flexibility does offer better opportunities for balancing systems with large shares of renewables and making the most of smart systems and storage resources. And this in turn may result in reductions in the costs associated with power generation and system operation; recent estimates of the potential savings derived from a successful implementation of demand-side flexibility programmes are in the order of hundreds of millions.

But how will this flexibility be implemented? Demand-side response comes about in two main ways: Reducing the overall level of usage at a particular site; Dynamically offsetting network supply constraints by shifting demand in time.

Measures of this sort have been used in the industrial sector for some time now, but there are several questions about the extent to which this kind of measure might be applicable and beneficial to residential users.

People's activities have a big impact in terms of flexibility, and the way flexibility programmes are implemented will in turn have a big impact on what people do while at home.

Differential pricing schemes in the form of so-called *Time of Use Tariffs* are currently the most common mechanism to try and persuade consumers to shift their energy demands to the times of day where the system is less constrained by offering a lower price than during peak times.
In principle, there are two ways of measuring the flexibility potential based on the implementation of Time of Use Tariffs.

***Approach 1*: Individual behaviour → price elasticity of energy**
This is basically a measure of the consumer's willingness to accept higher charges associated with the use of energy and how they respond to price stimuli. An interesting finding in this regard is that people would be willing to accept less compensation in the form of cheaper energy prices if they found that the time of use tariffs offered by their providers were easy to fit in their everyday lives.

Clearly, the traditional economic theory assumptions about rational, cost-reduction-seeking decision-making do not apply in this context, but then again, neither do assumptions about the paramount role of individual behaviour.

***Approach 2*: Activities as the unit of analysis**
New lines of research are using insights from theories of social practice to address these issues. Social practice theories provide a way of explaining the timing of demand, and the intrinsic flexibility – or indeed, the lack of it – associated with the different activities that feature in our everyday lives. Using activities as the unit of analysis, and paying special attention to the scheduling of those

activities, allows for the use of alternative methods such as the clustering of consumers based on what they do at peak times.

This, in turn, allows for the identification of groups of users that may be more or less susceptible to modify their energy consumption patterns, and the tailoring of time of use tariffs that target specific clusters and socio-demographic subgroups.

Distributional effects of time of use tariffs

There are certain activities that systematically fall within peak periods. Cooking, for instance is one of them, as considerable levels of food preparation activity are observed at dinner time, which is well within the peak period.

These relations have some serious implications in terms of the implementations of dynamic time of use tariffs, as these might impact different segments of the consumer base in different ways.

Peak to off-peak ratio:
Studying the effects of time of use tariffs is essential, as poorly designed time of use pricing schemes might have undesirable effects. For instance, if people were to carry on doing what they normally do on flat tariffs, mid-income and single parent families would be affected the most by fixed time of use tariffs aiming for overall peak demand reductions. The potential for this kind of effects raises questions such as:

> What happens to those who do not have the time and the means for benefiting from demand-side flexibility?
> Who will benefit the most from the implementation of time of use tariffs?
> Will families with higher purchasing power and better access to new technologies such as EVs benefit more from the advantages offered by these technological innovations while at the same time enjoy lower energy bills?

These interrogations show just how complex the challenges are associated with making the demand side more flexible, but if we are to successfully transition towards low-carbon systems where renewables are our primary source of energy, we need to answer these and many more questions about the nature of peak demand and the demand-side flexibility sooner rather than later.